NASA GRC

Ka Band Propagation Experiment

R. Acosta - PI

August 20, 2002

Summary of Review

1- Introduction and Rules for the meeting – R. Acosta
2- High Level Project Overview - D. Hilderman
3- Technical Overview and Status – R. Acosta
4- System Analysis – S. Johnson
5- Hardware Development Status - D. Kifer
6- Software Development Status – W. Feliciano
7 – Action Items - Acosta

Propagation Measurement and Analysis
GEO Propagation

Description and Objectives

- Enhance the Ka-band propagation database that was developed using ACTS by adding measurements in tropical regions.
- Improve the accuracy of ITU-R prediction models by increasing the zones where propagation data is collected
- Determine service availability supplied to the end users and predict the behavior of these systems when affected by high rain fading conditions.

FY03 Products

- Ka-Band GEO STENTOR propagation measurement results and updates to GRC models.

ACTS GEO Propagation Terminal

STENTOR GEO Satellite Model

Approach

- Continue to collect and characterize Ka-Band GEO propagation data at University of Puerto Rico.
- Update existing models for Ka-Band propagation.
- Disseminate information through technical reports and conferences.

PI's and Partners

- GRC/Dr. Roberto J. Acosta, Sandra K. Johnson, Walber Feliciano
- Florida Atlantic University/ Professor Henry Helmkin

- **FY03 Milestone and Deliverables**
- Q1 - Deliver progress report on propagation terminal operational status and data collection.
- Q3 - Collect and characterize one year of Ka-Band GEO propagation data.
- Q4 - Update existing models and reports for Ka-Band GEO microwave propagation.
- Q4 - Report on first year of propagation data and disseminate information through appropriate technical reports and conferences.

Application/Missions

- Future NASA, DoD and commercial GEO missions with data return requirements exceeding current ground network capacity or proposing Ka-band links.

Propagation Measurement and Analysis
LEO Propagation

Description and Objectives

- Develop LEO propagation terminals to enable future characterization and modeling of the effect of rapidly varying atmospheric conditions on Ka-Band signal transmission from LEO spacecraft to ground
- Develop first-ever, world-class LEO propagation measurement techniques and experiment plan in collaboration with international partners

FY03 Products

- Ka-Band LEO propagation terminal, measurement techniques and experiment plan

Prototype LEO Tracking Terminal

Approach

- Integrate LEO ground station with beacon receiver, radiometer, mechanical tracking system and software control.
- Conduct LEO ground station on-orbit tracking verification with ACTS and/or LEO satellite.
- Disseminate information through technical reports and conferences.

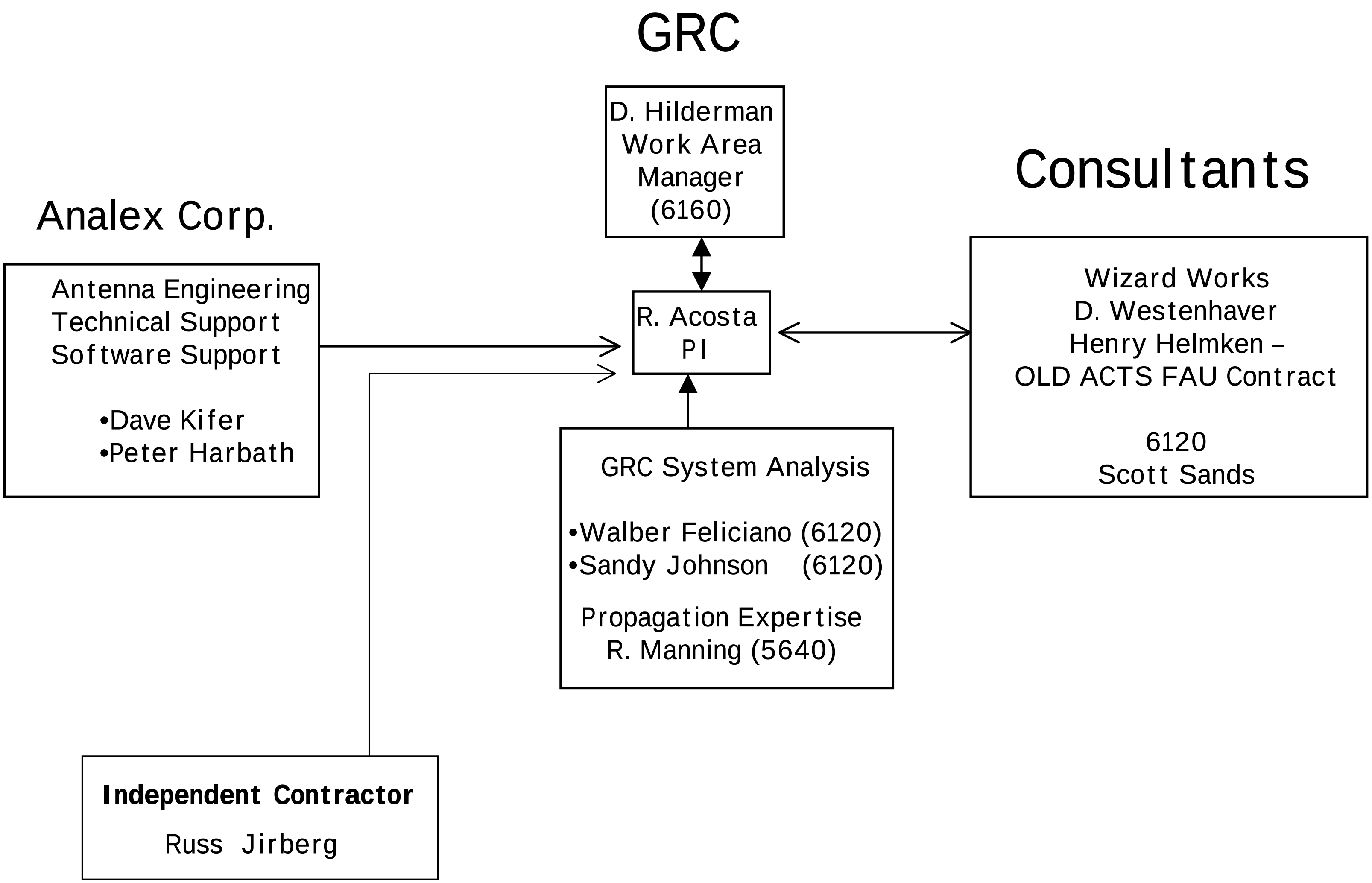
PI's and Partners

- GRC/Dr. Roberto J. Acosta, Sandra K. Johnson, Walber Feliciano

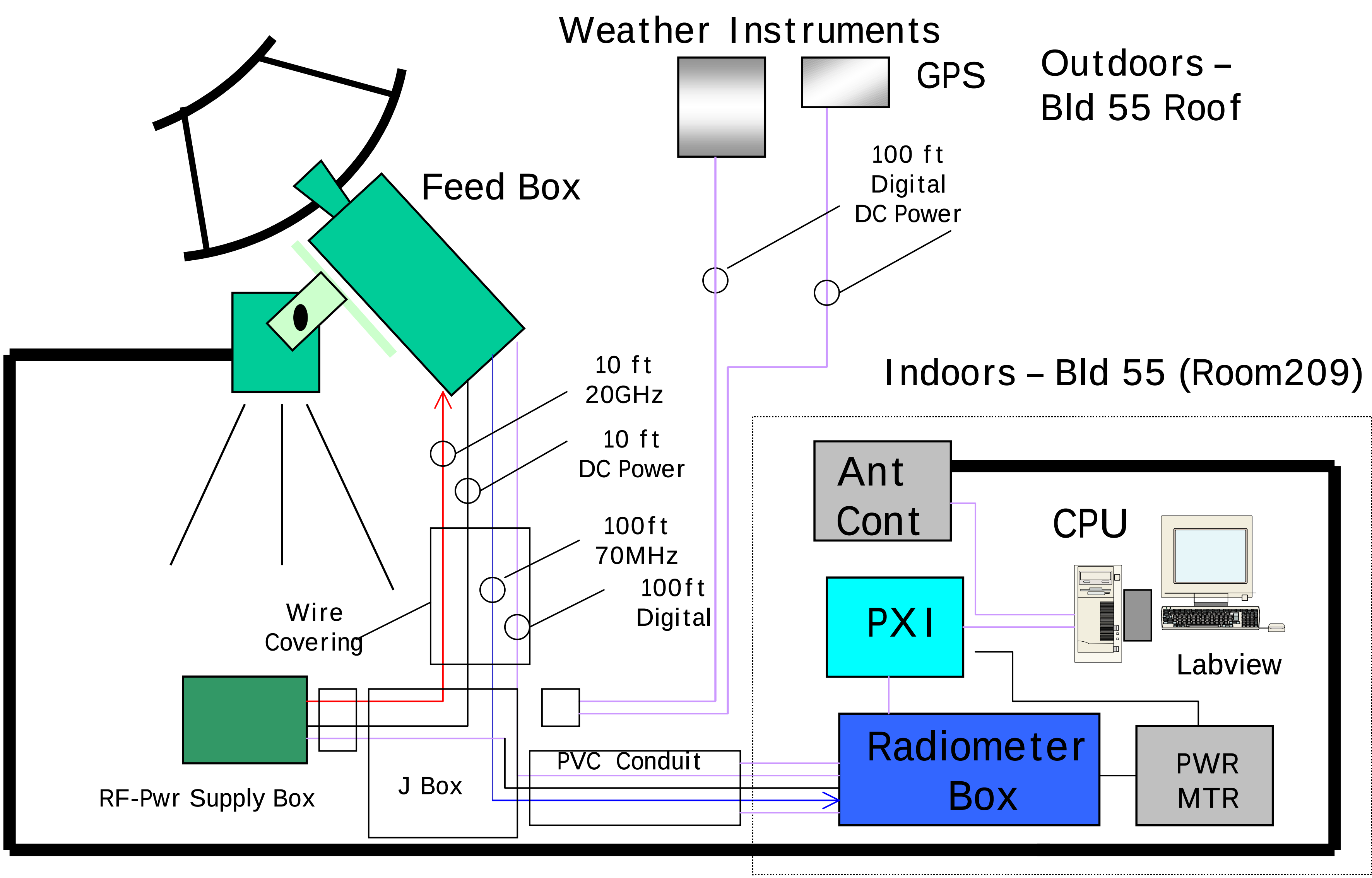
FY03 Milestones and Deliverables

- Q1 – Plan, design and disseminate experiment information on Ka-Band LEO propagation experiment with DAVID satellite
- Q4 – Deliver progress report on propagation terminal, its operational status and experiment plans
- **Application/Missions**
- All future NASA LEO missions with data return requirements exceeding current crowded X-Band ground network capacity
- International planning committees for utilization of Ka-Band allocations globally
- Efficient system design of future low cost, wideband direct-to-user tracking ground stations

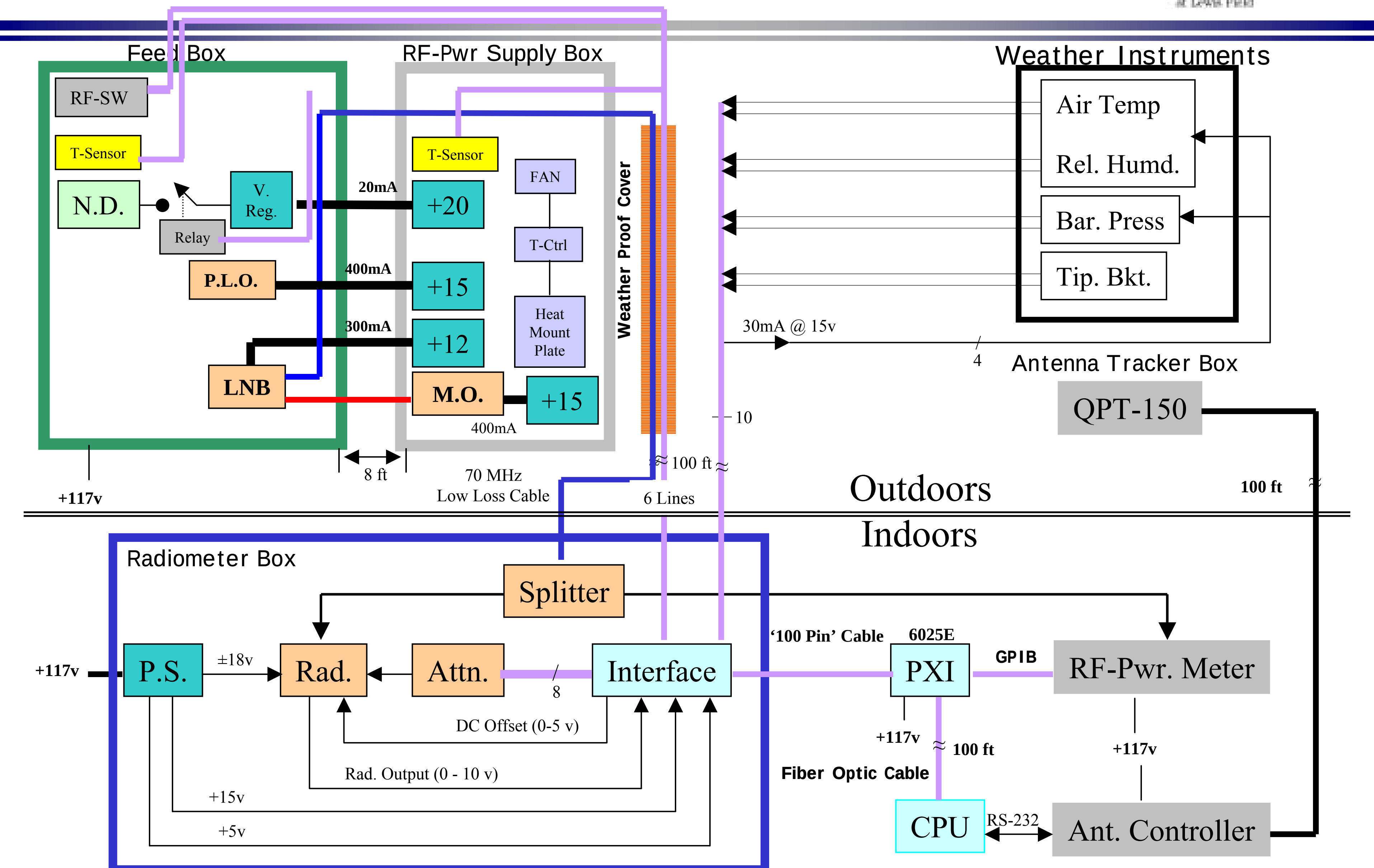
Team Structure (8-20-02)



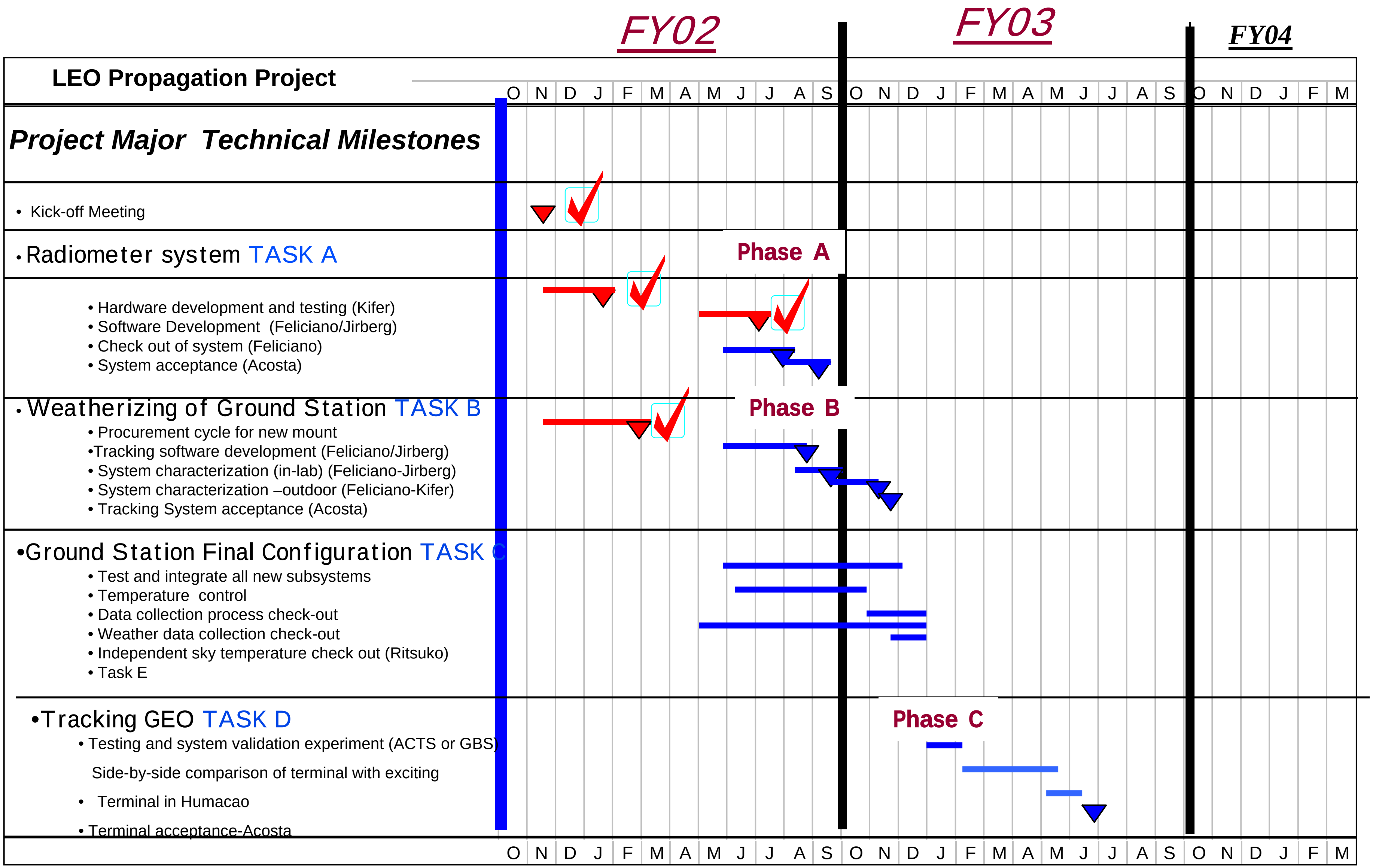
Architectural Design
GRC LEO/GEO Ground Station



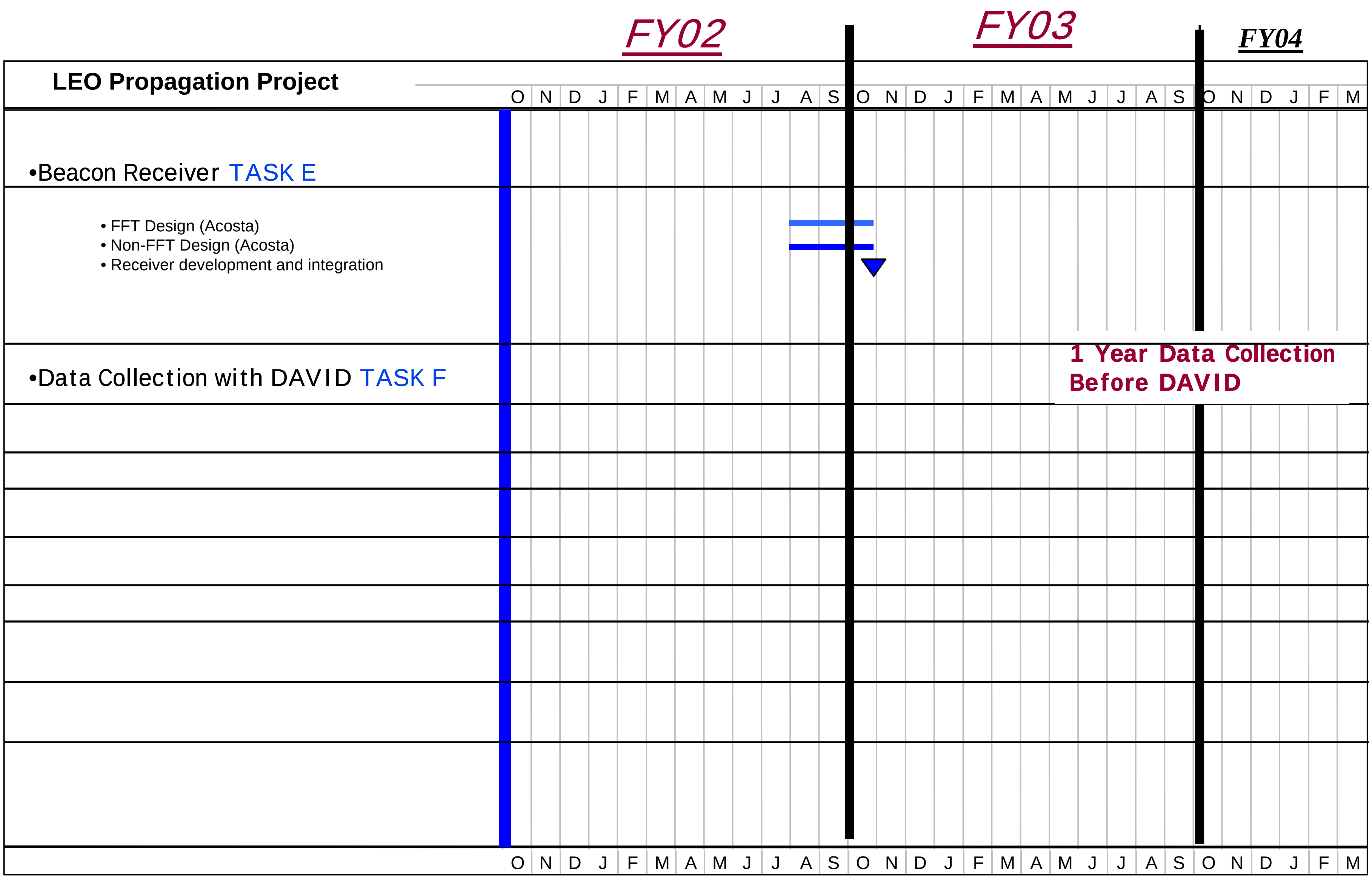
System Block Diagram



Propagation Project Schedule



Propagation Project Schedule



Preliminary Configuration
Outdoors Testing

New GRC LEO/GEO Propagation Ground Station
(GRC In-House Design)

Preliminary Data Collection System Block Diagram

New GRC LEO/GEO Propagation Ground Station Data Collection System

New Preliminary GRC LEO/GEO Propagation Ground Station

Feed Window
(By Dave Kifer)

HARDWARE DEVELOPMENT

D.Kifer

05/02dk

Project Review

Roof Top RF Power Supply

New cabinet on order

Expect delivery September 1st

Work required on Cabinet

Modify for vents and fan

Mount and install 3 miniature power supplies

Spec. for design, procure, and install various feed-thru connectors for power and RF

Feedbox

Will attempt to continue to utilize single cable pass-thru connector in cabinet. If this doesn't work, multiple feed-thru connections are recommended.

Project Review cont. 2

Radiometer / Power Supply Cabinet

Temperature variation measurements complete.

Room Air Temperature	26C	
Input Air Vent	26C	Taken outside of cabinet
Output Air Vent	33C	Taken outside of cabinet

Measurements were taken at several spots within the components. The following values were the highest temperatures within that component.

	Cover Open	Cover Closed
Power Supply	49C	57C
Radiometer	35C	37C
.5" Air space between PS and Radiometer	35C	37C

Additional RF Coax connectors will be required.

Current Power and Data connections will need to be changed to incorporate the re-design.

Roof Top Cable & Protection

Ultra Low-Loss Cable for 70 MHz Signal from Feedbox to Radiometer on order.
Expected delivery is August 26, 2002.

Cables from Feedbox to Tripod Cabinet
Current plan is to use solid plastic “loom”.
Once the entire cable bundle is assembled and complete, a final decision will be made based on size, weight and flexibility.

Cables “on” Roof

Suggest using outdoor PVC Electrical Conduit (similar to conduit used at U of P.R. – Humacao). Other options do not fit well with our concerns for cable safety.

Anticipate replacing the “remote” indoor/outdoor power & R.F. cables currently used, due to the changes in where the various components will be located in the new version.

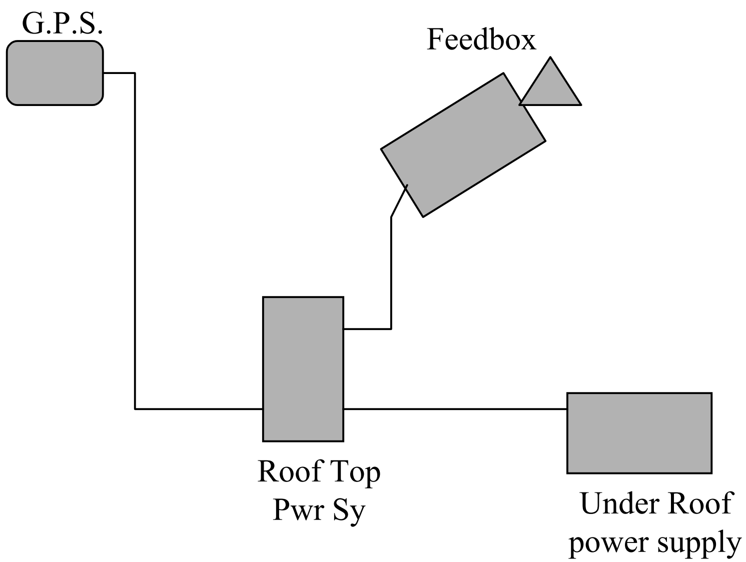
Project Review cont. 4

G.P.S.

Antenna mount required modification.

The threads used for mounting were metric, and NOT normal tapered pipe threads.

Parts available require tapered threads. The plastic mount was successfully "bound" and re-tapped.



Question whether the RoofTop P.S. Cabinet should be used as a "data" pass-thru, or just run cables direct, bypassing cabinet.

Cables just passing through the cabinet add connectors, thereby increasing possible failure points.

Ortho Mode Transducer and Polarizer

20.700GHz for GBS & Stentor

Similar to units previously purchased for other projects..

I made contact with sales at Millitech, LLC ., parts available within 45 days.

Order is in Glenn purchasing system.

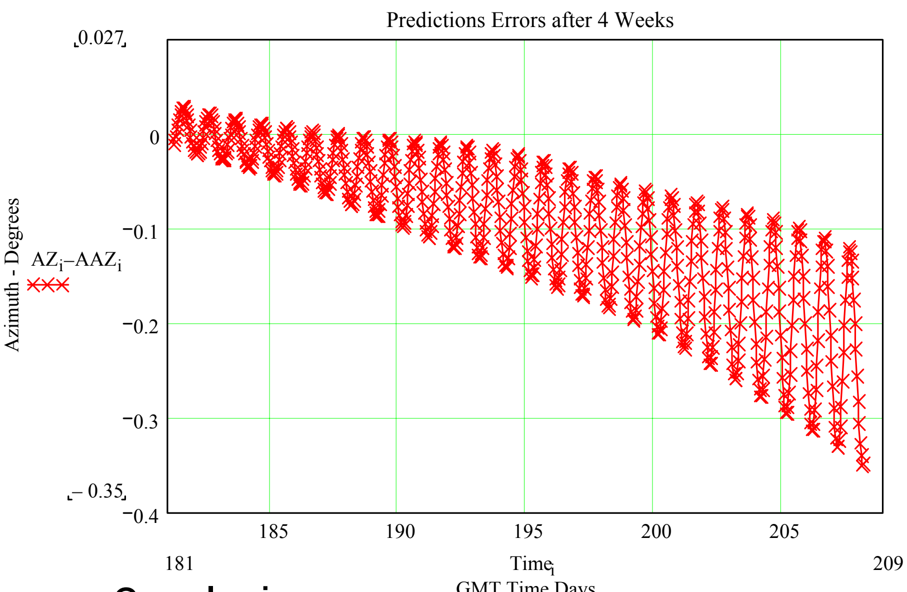
I would prefer to run the RF/Pwr Sy box, Weather Station and GPS cables to a single junction box, then run all cables from the roof to the indoor equipment in one conduit.

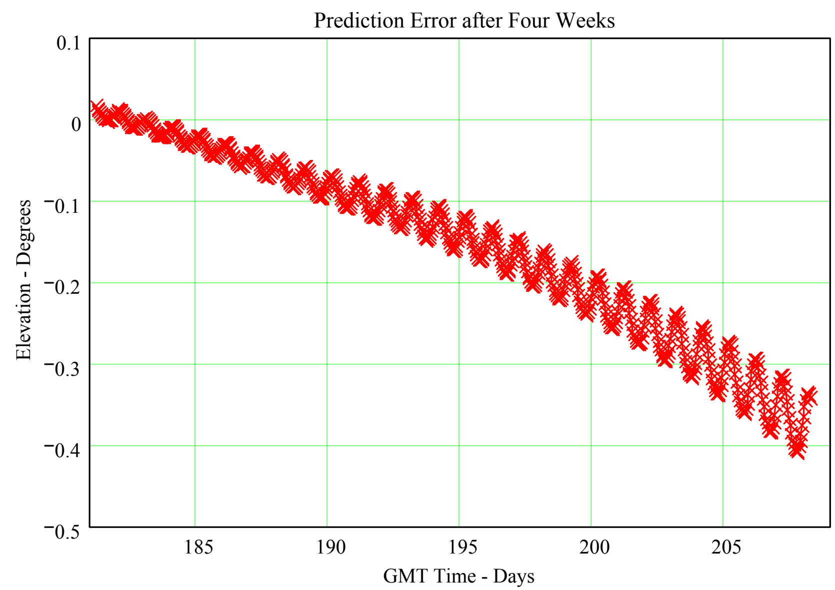
GRC SPG4 – Software Validation, Pointing Error, GBS Orbit Drifts

S. Johnson, R. Acosta, O. Olawatosin, K. James

GRC Propagator Software Validation

Comparison of GRC SGP4 with STK MSGP4





Conclusions

STK MSGP4 includes Sun and Moon gravitational fields as well as sectoral and tesseral Earth harmonics. This factors are necessary for orbit greater than 3 Hrs.

GRC SGP4 does not includes this factors. In order to used the GRC SGP4 CODES for GEO orbits predictions, it is required to add the above mentioned factors to the codes.

Comparison of GRC SGP4 with STK MSGP4

Conclusions

GRC SGP4 Codes are valid (in-theory) for LEO orbits with less than 3 Hr periods. This orbits does not required the Sun and the moon factors.

GRC SGP4 Codes are not valid for GEO orbits. **Sun and Moon effects needs to be incorporated into the codes.**

Conclusions

GRC Software Validation

ACTION ITEM #1:

1. **Sun and Moon effects needs to be incorporated into the codes. In addition higher order modes are also required for orbit with periods greater than 3 Hrs.**
2. **Re-Do analysis after all factor are incorporated for model validation**
3. **Performed same analysis for LEO orbits (e.g Shuttle, Space Station and LEO)**

Pointing Error Analysis

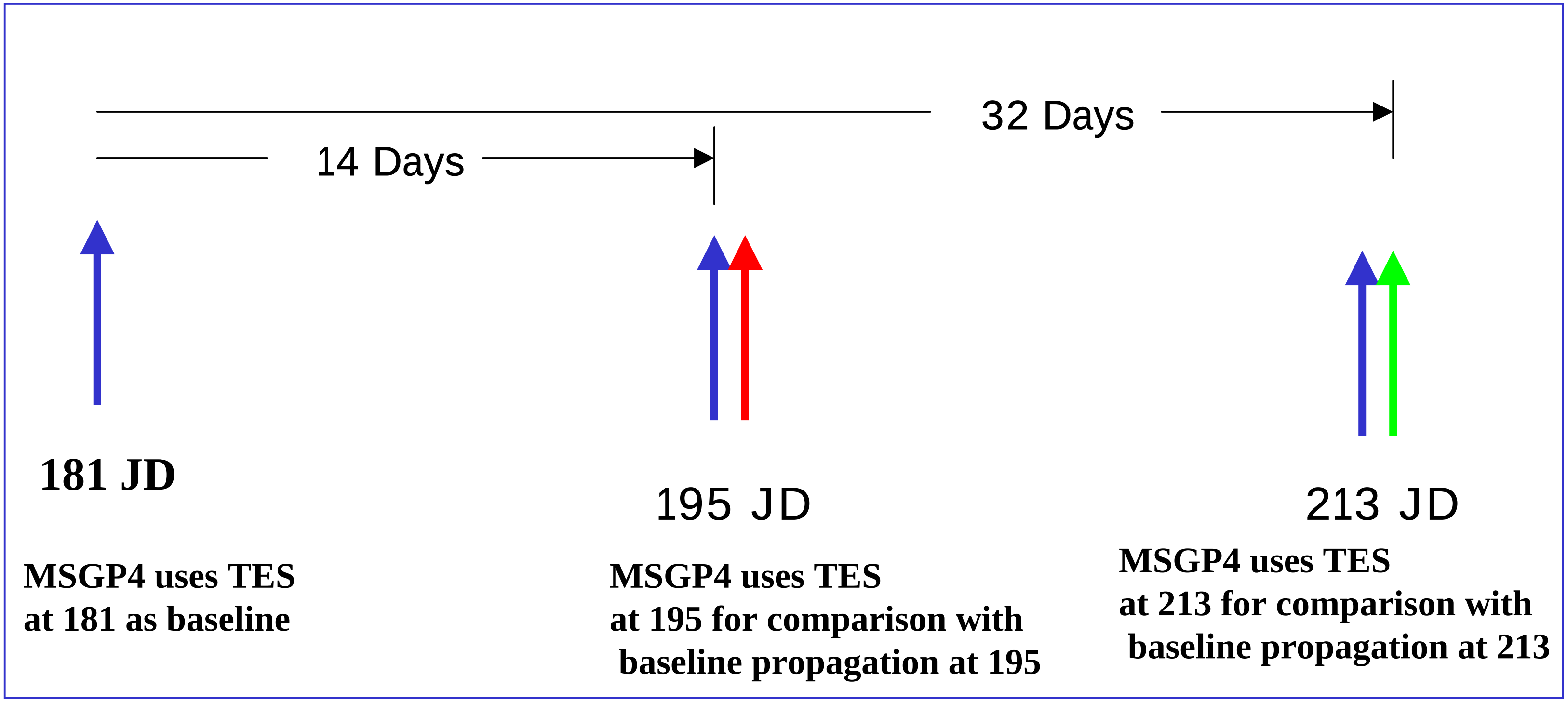
How often do we need to update the two element set and therefore update the pointing tables **<u>for GEO</u>** ?

Pointing Error Analysis

Analysis assumptions –

1- Given TES at Julian 181, 195 and 213.

2- Use the MSGP4 propagator

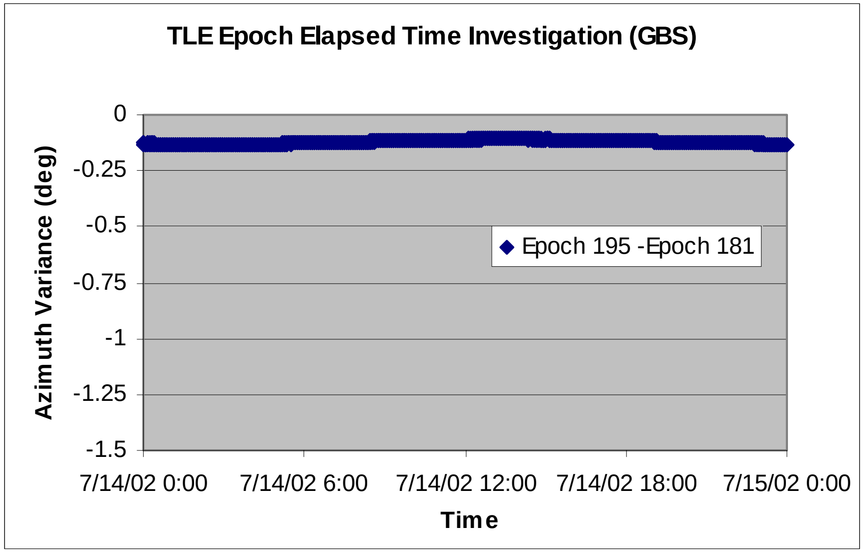


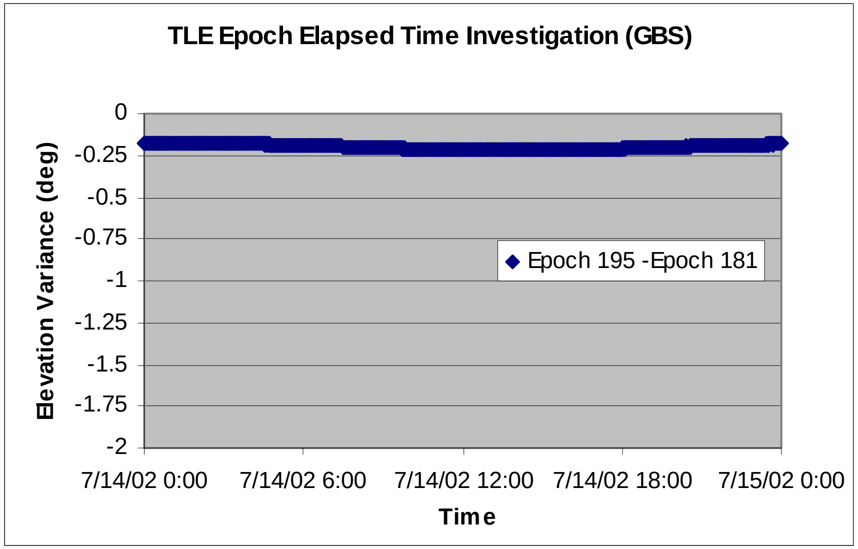
Time base for the calculations

*** TES = Two Element Set**

Pointing Error Analysis

Two weeks propagation from baseline (JD 181) compared with an update at JD 191

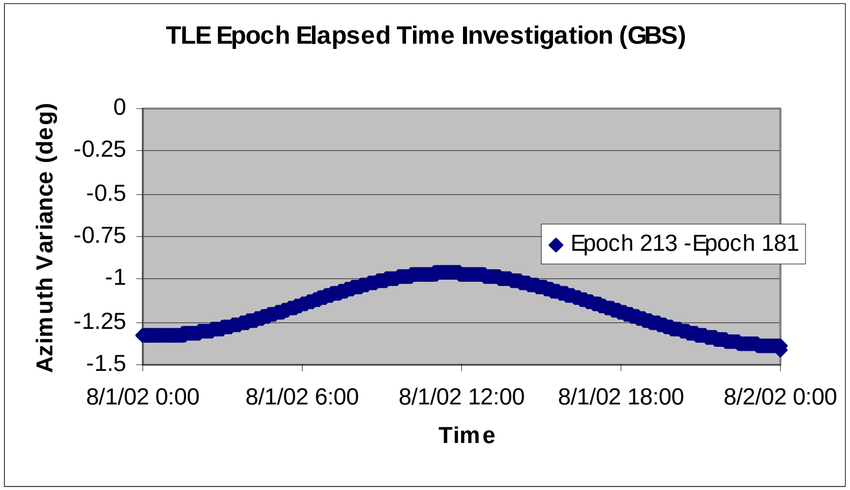


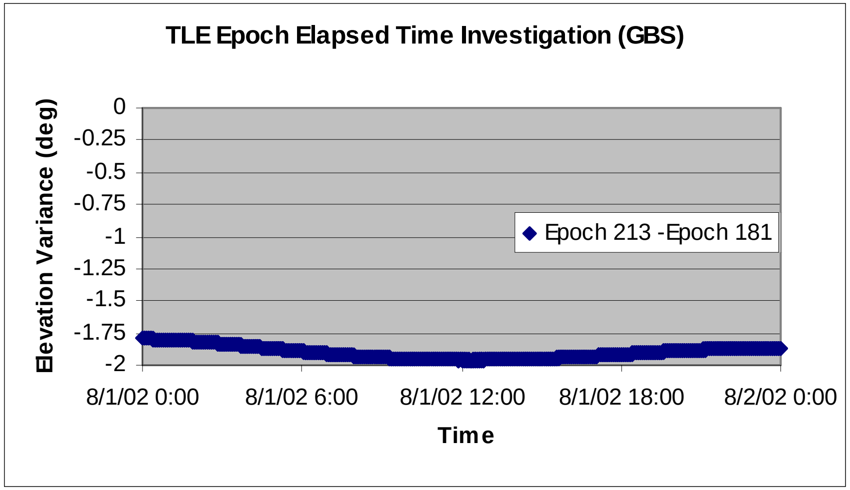


Conclusions - The baseline propagation shows an error less than 0.25 degrees (In azimuth and elevation) after two weeks. Antenna pointing loss is less than 2dB.

Pointing Error Analysis

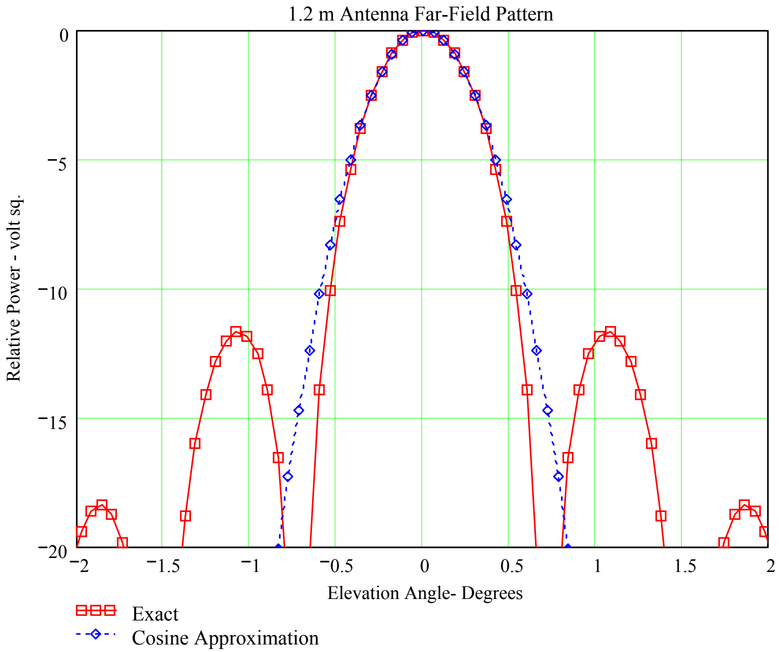
Four weeks propagation from baseline compared with an update at JD 213



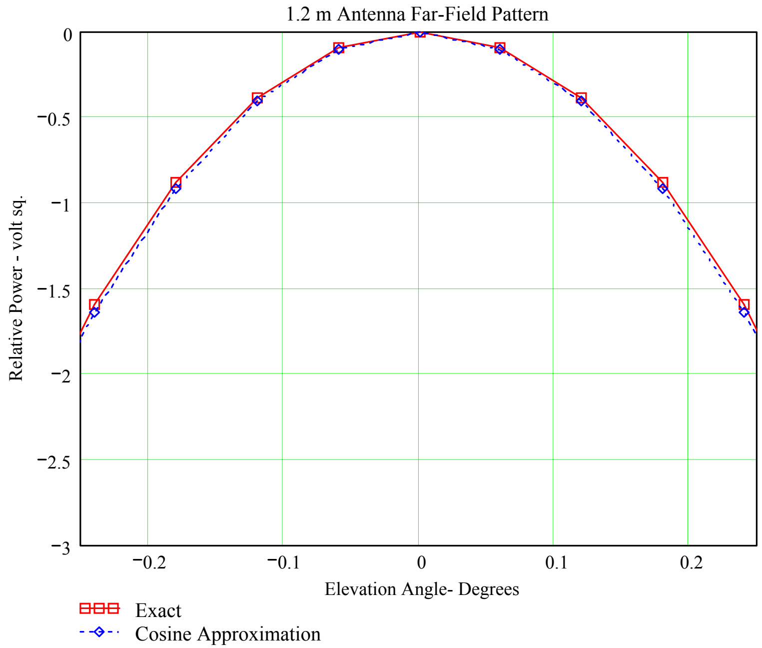


<u>Conclusions</u> - The baseline propagation shows an error less than 2.0 degrees (In azimuth and elevation) after four weeks. Antenna pointing loss exceeds than 15dB. In this case pointing is into the sidelobe region.

Pointing Error Analysis



Pattern at the 2 degree extreme



Pattern at the 0.25 degree extreme

1.2 m Antenna Pattern

Pointing Error Analysis

<u>Conclusions</u> - The analysis conclusively shows that 2 weeks of pointing tables evry two week will cause pointing errors of at least 2 dB. <u>(not acceptable for the project)</u>

Error of less than 0.5 dB are achievable if updates are performed weekly for GEO orbits. <u>(project requirement)</u>

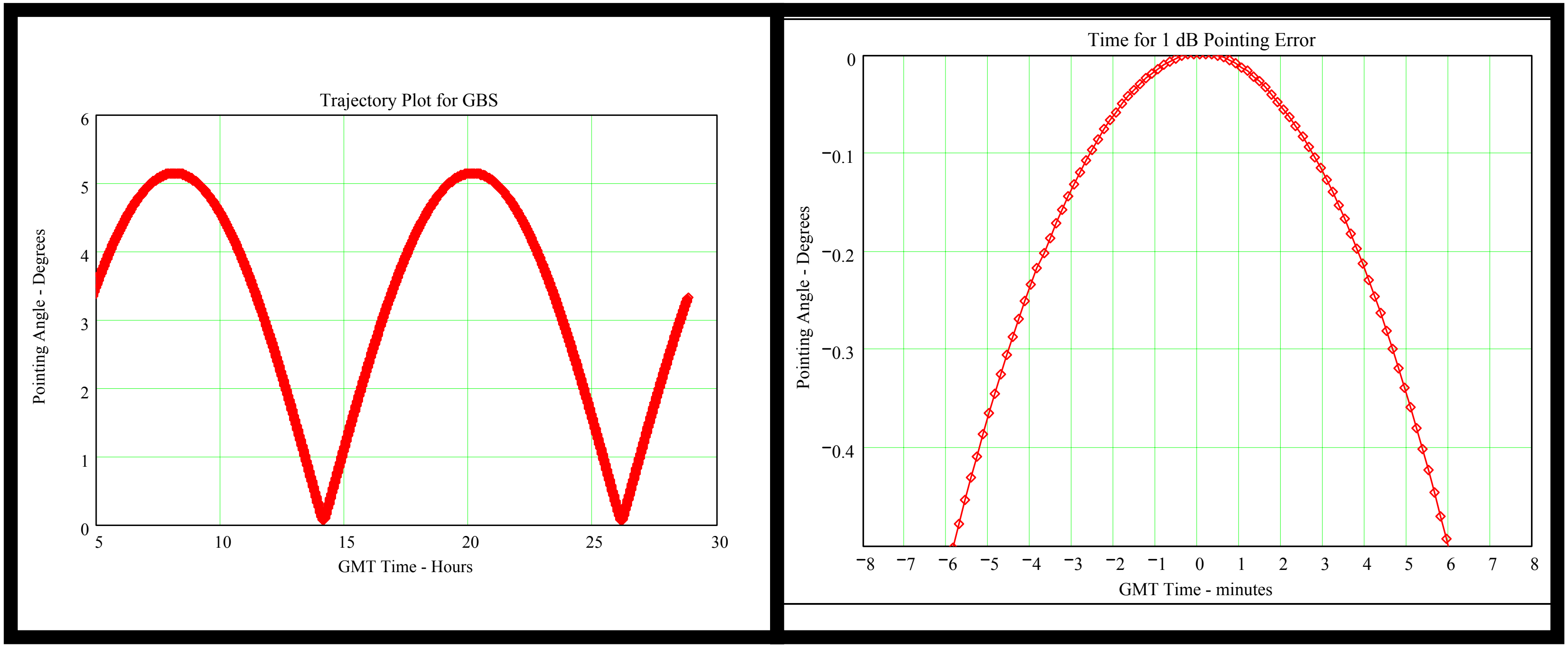
ACTION ITEM #2:

1. **Re-do pointing error analysis and the required update frequency for LEO orbits (e.g.,Shuttle,Space Station and LEO.**

Pointing Error Analysis

How often do we need to track or move to a new azimuth and elevation angle so that the pointing error is better than 0.5 dB for a **for GEO** ?

Pointing Error Analysis



<u>Conclusions</u> - For 0.5 dB pointing loss or less the antenna needs to be move every <u>6 minutes or less</u>.

ACTION ITEM #3:

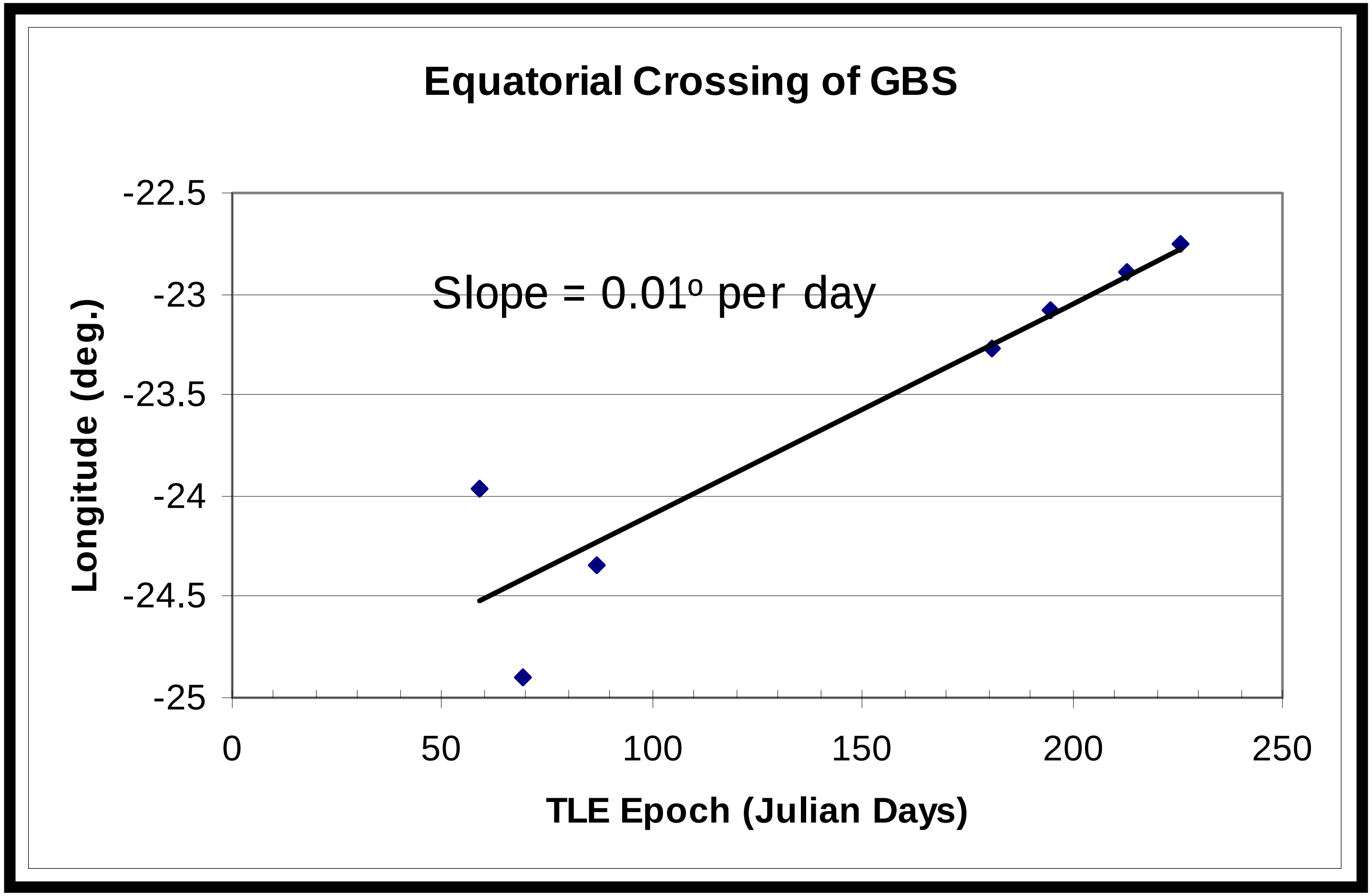
1. Re-do analysis for the required antenna pointing steps time for LEO orbits (e.g.,Shuttle,Space Station and LEO.

Pointing Error Analysis

GBS un-explain East-West drifts

GBS Orbit Drifts

(East-West)



Conclusions - Satellite maneuvers and drift of GBS will cause pointing errors if the actuators are not re-adjusted about the center of motion

ACTION ITEM #4:

1. **Find GBS old TES and recalculate drifts.**
2. **Continue to monitor Drifts**
3. **Investigate the impact of drifts on Humacao ground station**

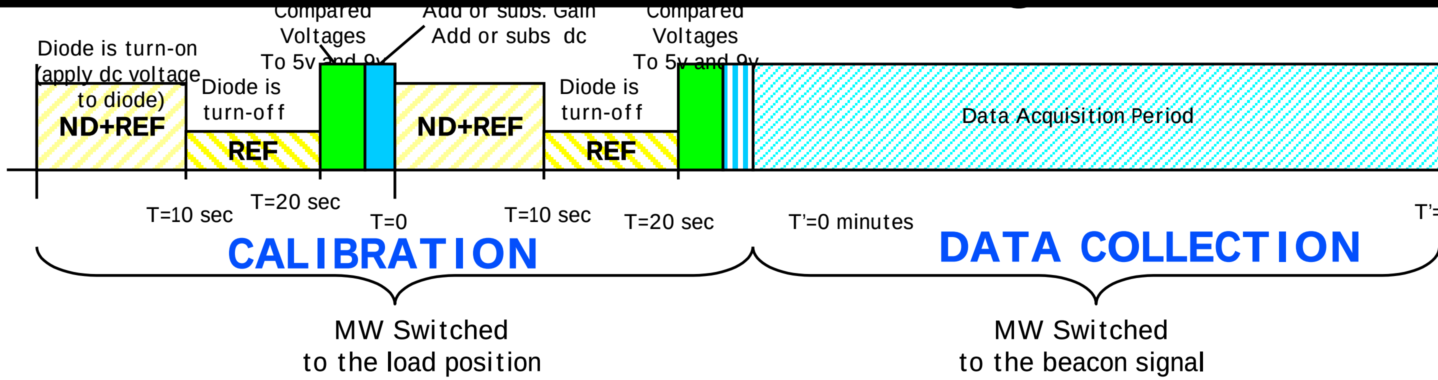
Software Development

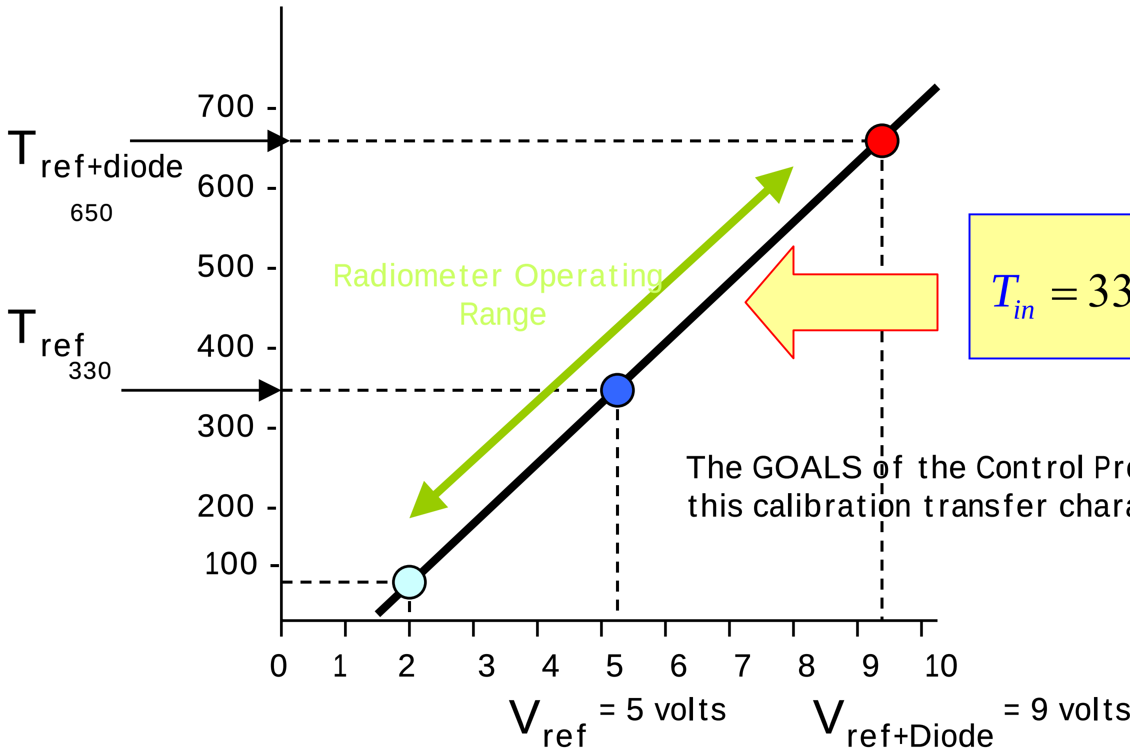
Propagation Terminal

By: W. Feliciano

Radiometer Software Calibration Algorithm

Process is repeated until Measurements are interrupted by DC power failure or Any other reason

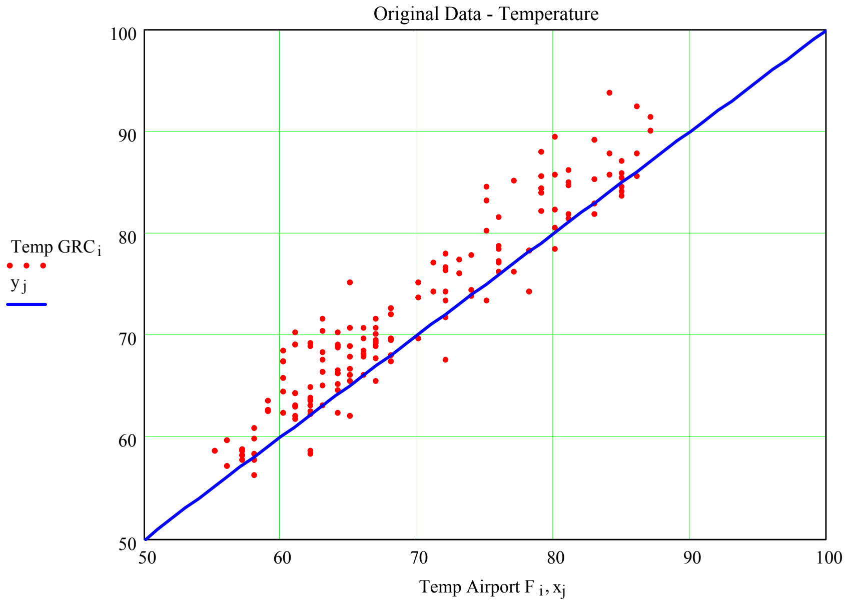


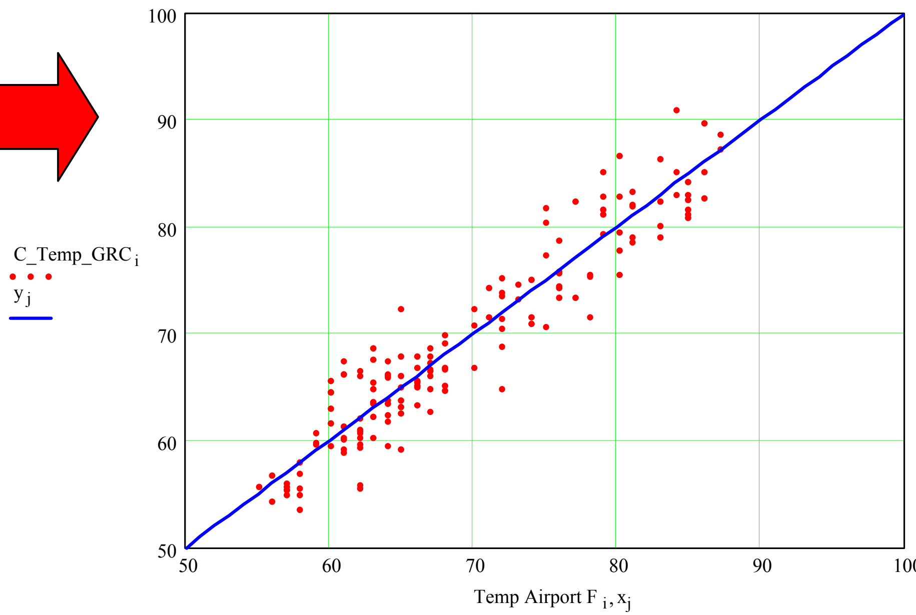


$$T_{in} = 330 + \frac{650 - 330}{9 - 5} \cdot (V_{out} - 5)$$

The GOALS of the Control Program and Calibration routine is to achieved this calibration transfer characteristics after each calibration sequence.

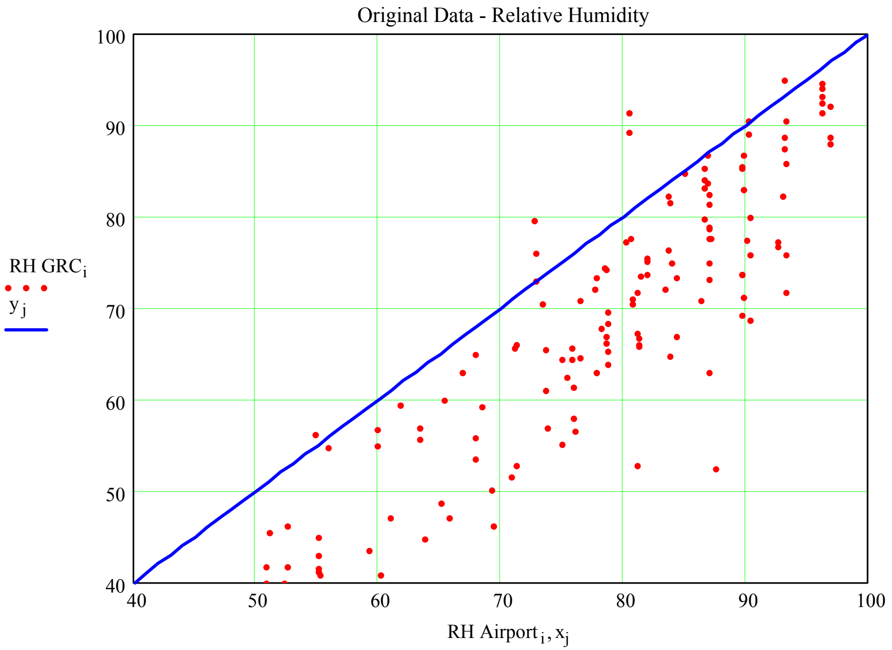
Weather Data Status

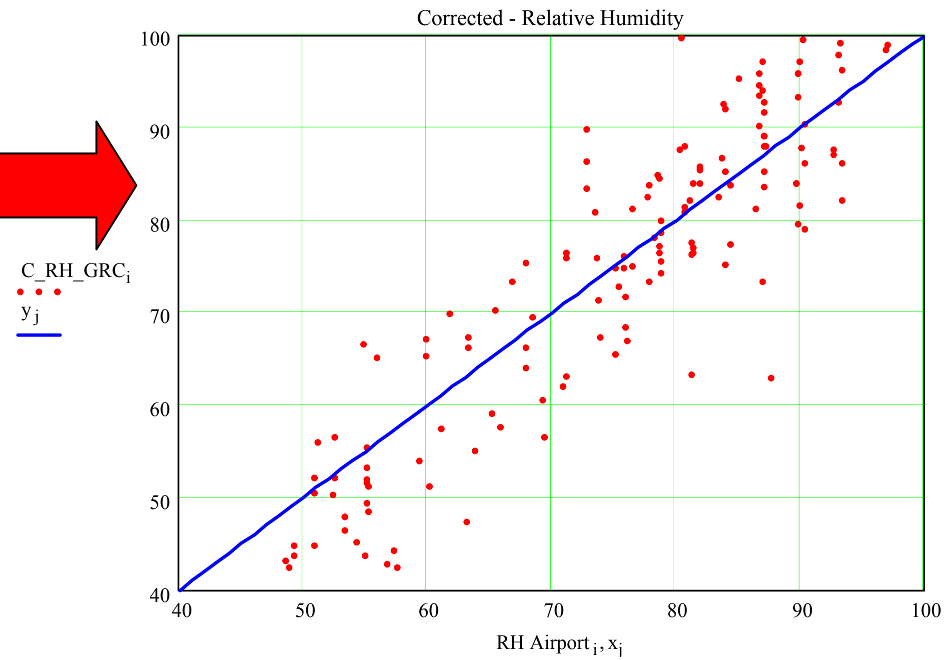




Before and After Calibration GRC vs Airport Outdoor Temperature

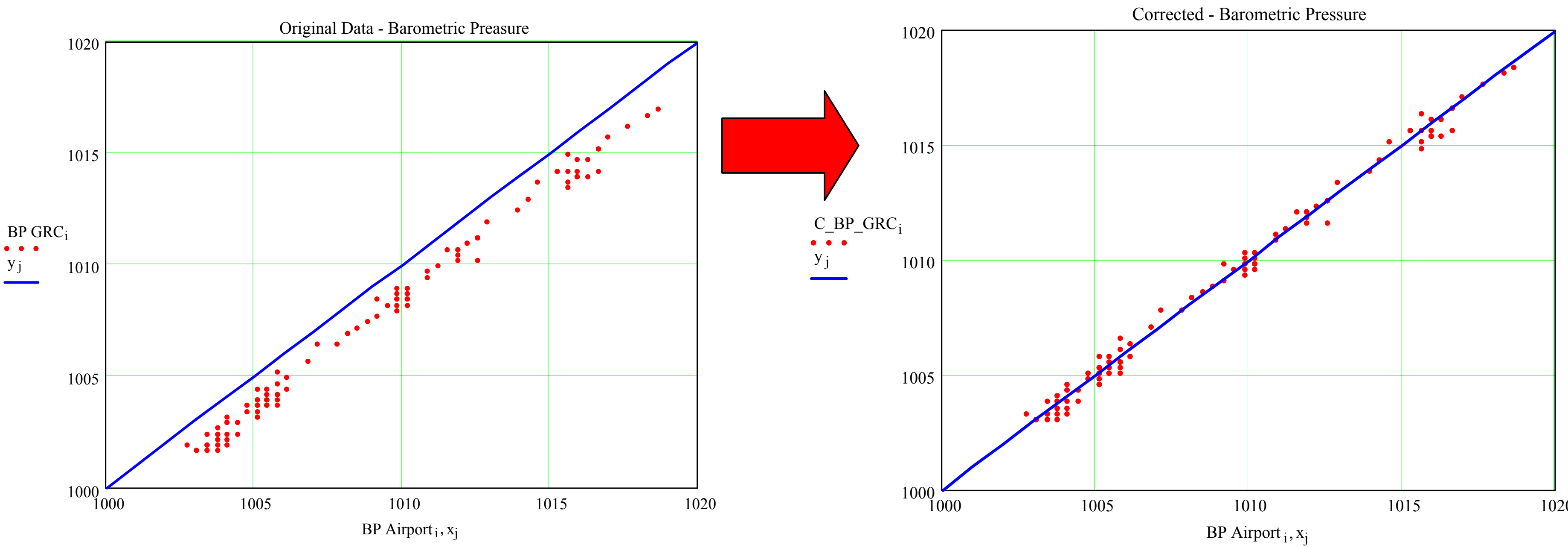
Weather Data Status





Before and After Calibration GRC vs Airport
Outdoor Relative Humidity

Weather Data Status



Before and After Calibration GRC vs Airport Outdoor Barometric Pressure

Tipping Bucket Data Status

Statistics

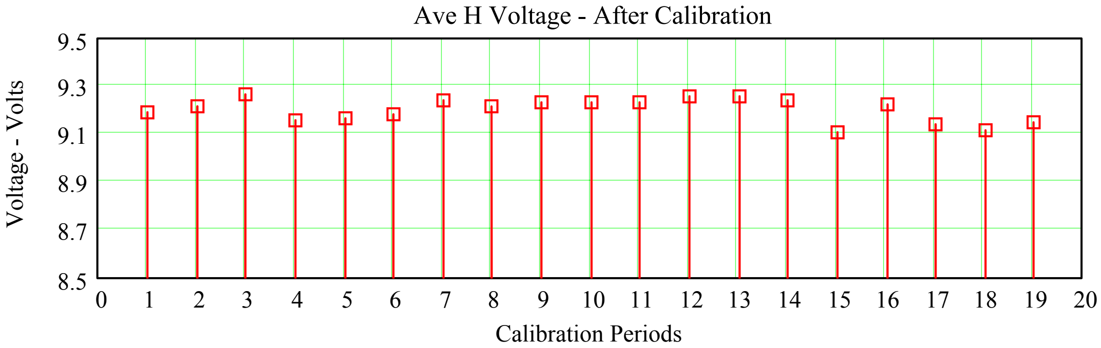
Compared data to airport cumulative distributions

ACTION ITEM – Walber is updating this chart

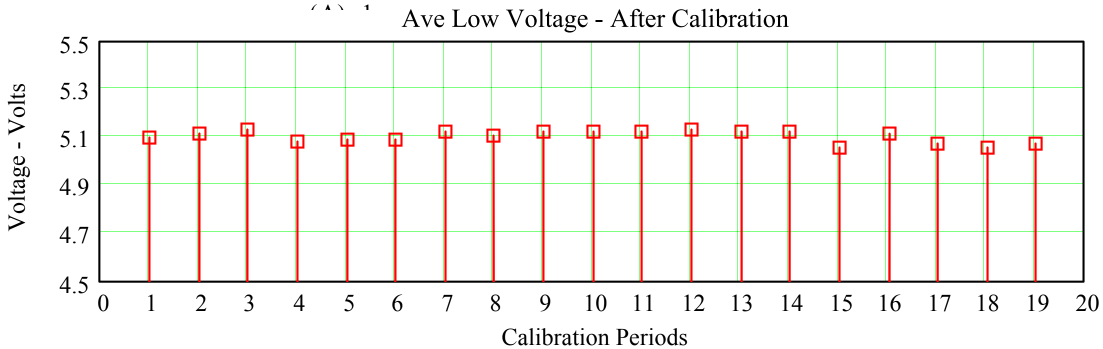
Radiometer Software Status

Bench Testing

Calibration Statistics - Stability of Algorithm Calibration



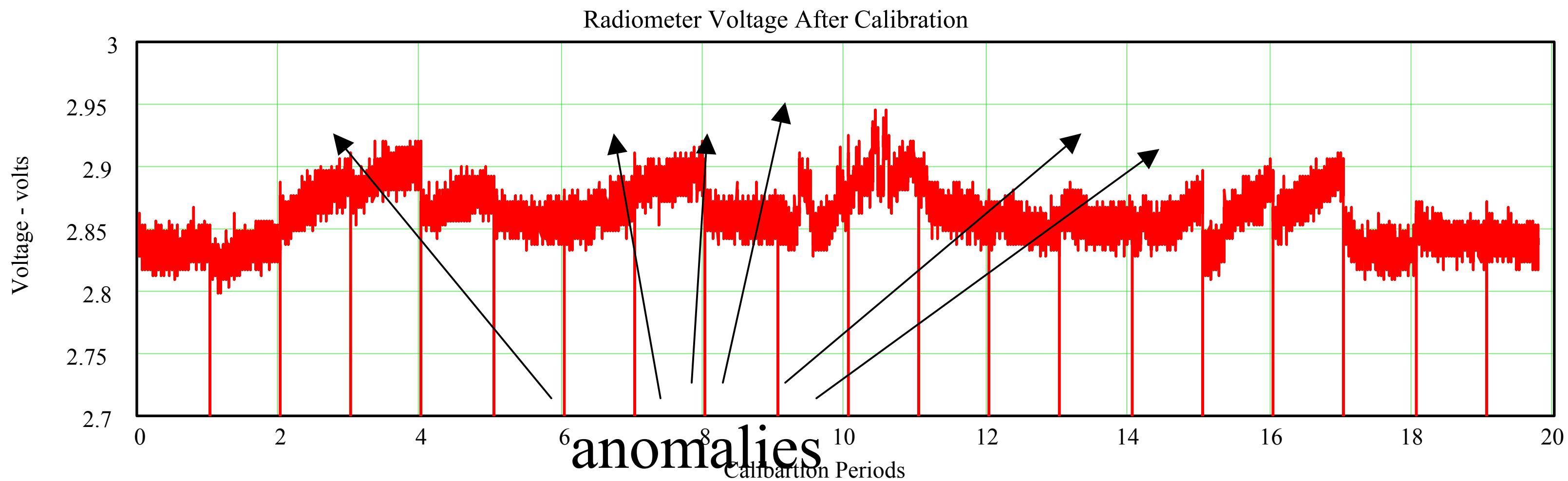
Mean = 9.198 volts
STD = 0.048 volts



Mean = 5.101 volts
STD = 0.025 volts

Radiometer Software Status

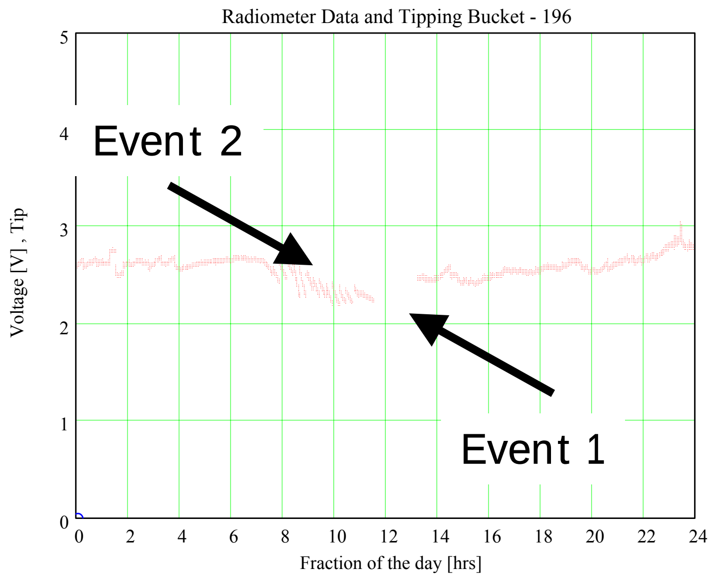
Bench Testing – 5 Hrs data Collection Period



Radiometer Software Status

Test Results - Outdoors

- Temperature related anomalies found:
  - Event1: gaps of no data were observed
  - Event 2: Large fluctuations in the voltage reading during data acquisition periods (between calibration times were noticed) Critical time 8am to 12pm.



Radiometer Anomaly Test #1

- Bench Test: 'Heat Gun Test'

<u>Test Description:</u>

A 'Heat Gun' test was conducted to verify the radiometer Output Voltage characteristics break down under heating and cooling conditions.

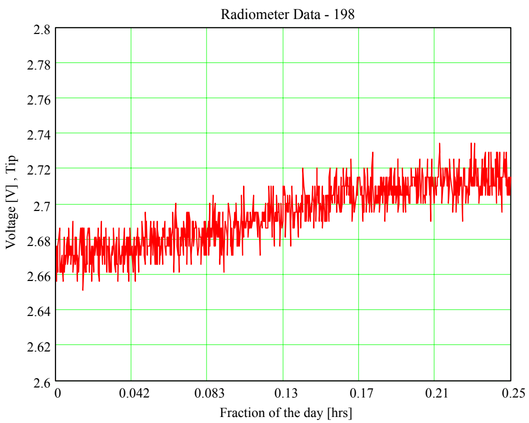
-Calibration frequency is 30 seconds
-Data collected for approximately 15 min.

<u>Conclusions:</u>

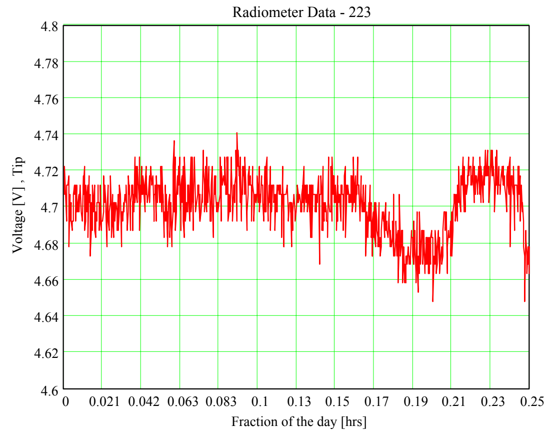
-Output voltage behave the same as was seen on event 2 when heat is applied and removed from the radiometer box

ACTION ITEM – Walber is updating this chart

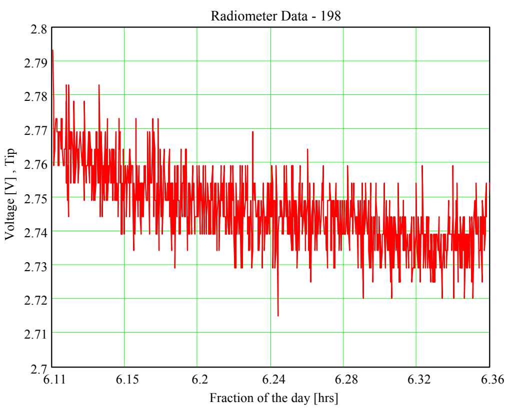
Radiometer Anomaly Test #2



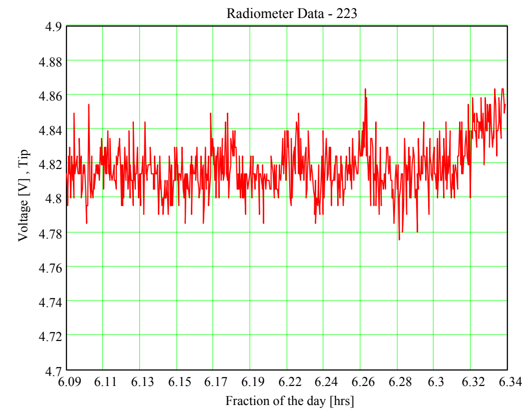
At ≅ 0 hrs
Rad_{mean}= 2.694
Rad_{stdev}= 0.017



At ≅ 0 hrs
Rad_{mean}= 4.701
Rad_{stdev}= 0.016

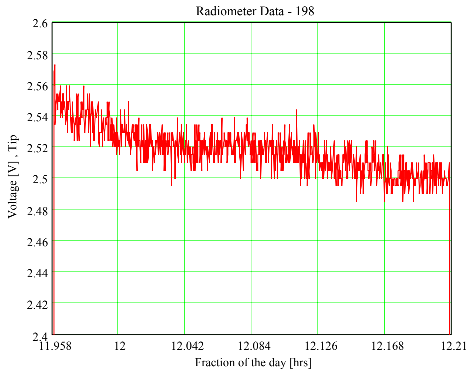


At ≅ 6 hrs
Rad_{mean}= 2.747
Rad_{stdev}= 0.011

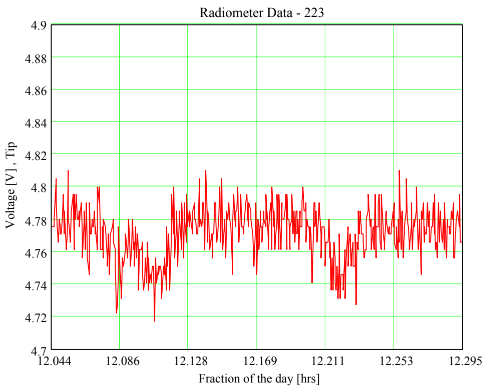


At ≅ 6 hrs
Rad_{mean}= 4.817
Rad_{stdev}= 0.015

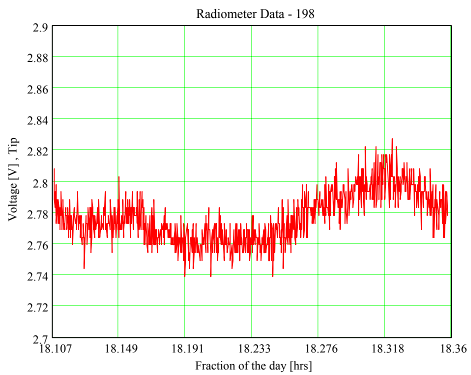
Radiometer Anomaly Test #2



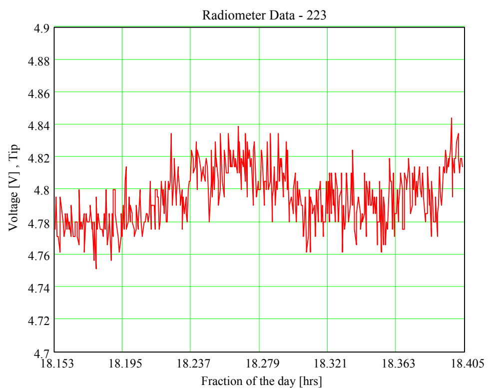
At ≅ 12 hrs
Rad_{mean}= 2.518
Rad_{stdev}= 0.015



At ≅ 12 hrs
Rad_{mean}= 4.771
Rad_{stdev}= 0.016

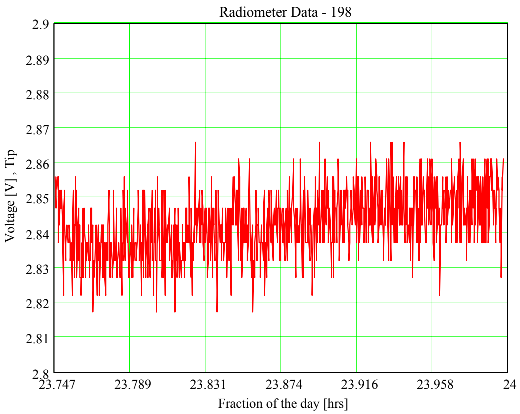


At ≅ 18 hrs
Rad_{mean}= 2.777
Rad_{stdev}= 0.016

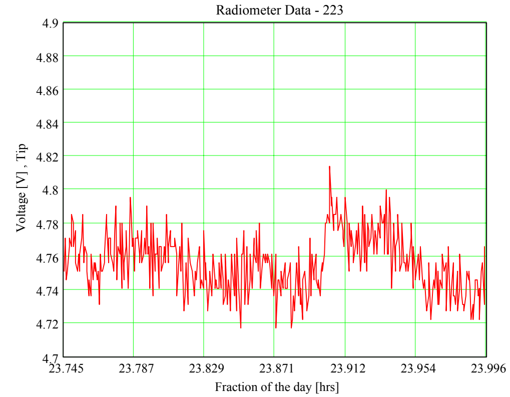


At ≅ 18 hrs
Rad_{mean}= 4.795
Rad_{stdev}= 0.018

Radiometer Anomaly Test #2



At $\cong$ 24 hrs
Rad_{mean} = 2.842
Rad_{stdev} = 0.009



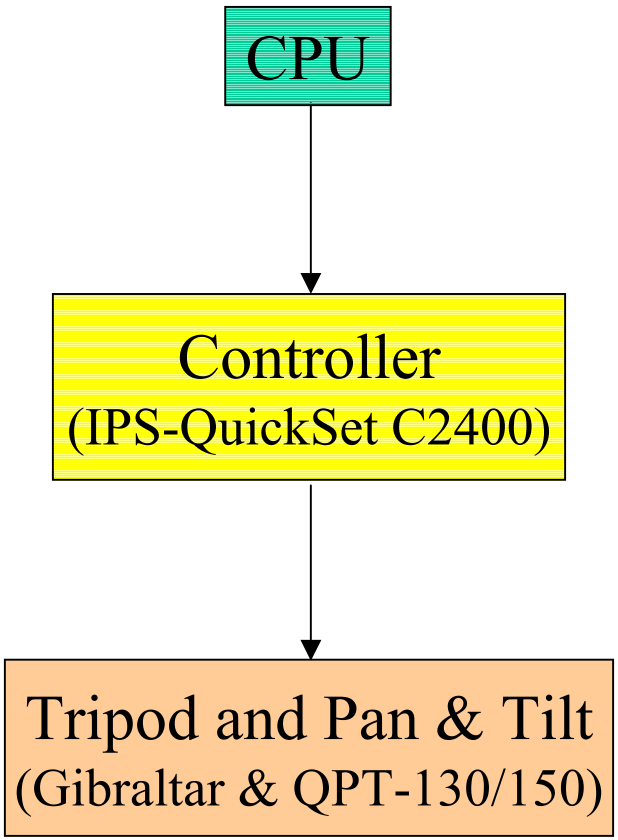
At $\cong$ 24 hrs
Rad_{mean} = 4.756
Rad_{stdev} = 0.017

Conclusions:

-At these particular times we found that the std indoors and outdoors is about the same as

Tracker Characterization

Tracking Hardware

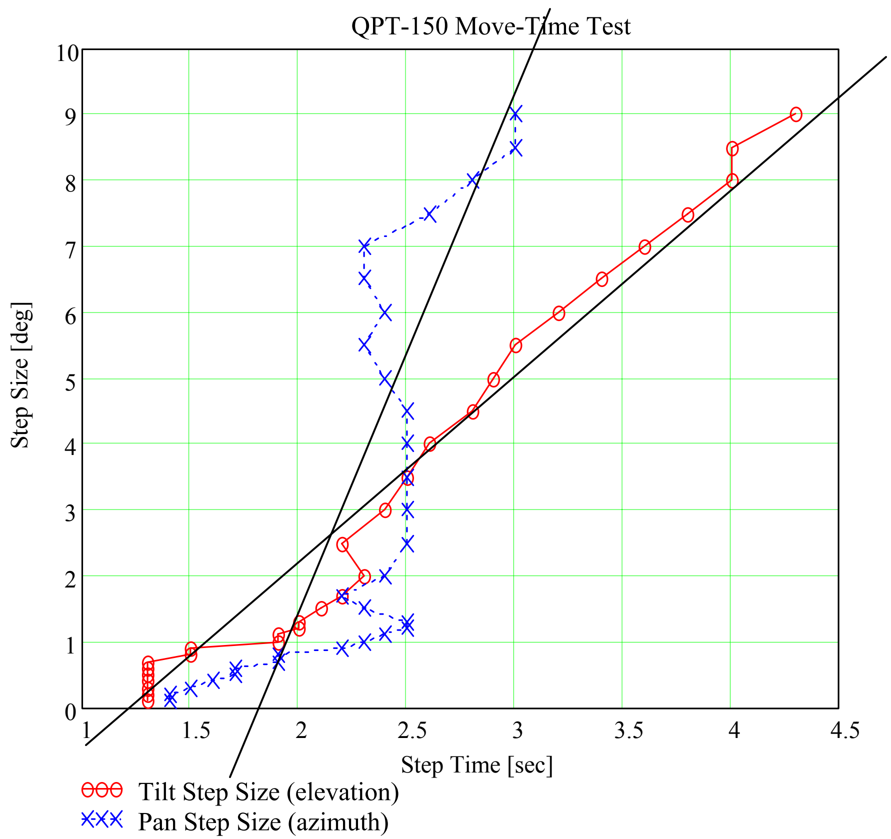


Tracking Software Status

- ✓Command structure understood
- ✓Labview commands developed
- ✓Tracking ability characterization

Tracker Characterization

Conclusion- Hardware capable of tracking GEO satellites (ACTS)
GEO Requirement = 0.1 deg/sec slopes
Measurements at GRC > 1 Deg/sec slopes

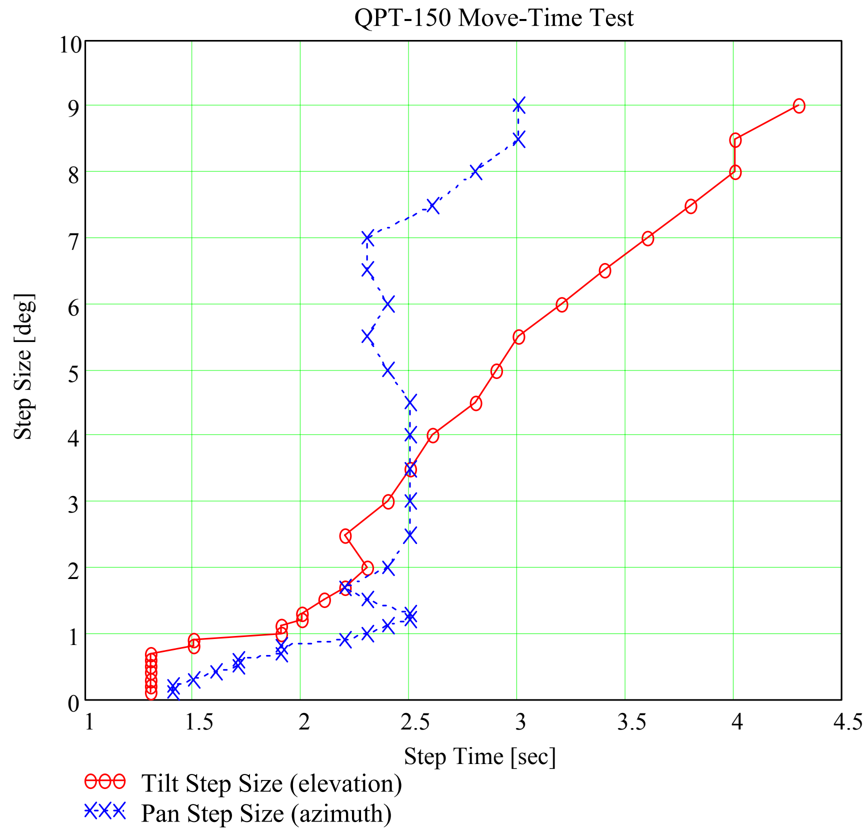


Tracker Characterization

Conclusions - **Hardware capable of tracking LEO satellites (David)**

LEO Requirement = 2 deg/sec slopes

Measurements at GRC < 2 Deg/sec slopes

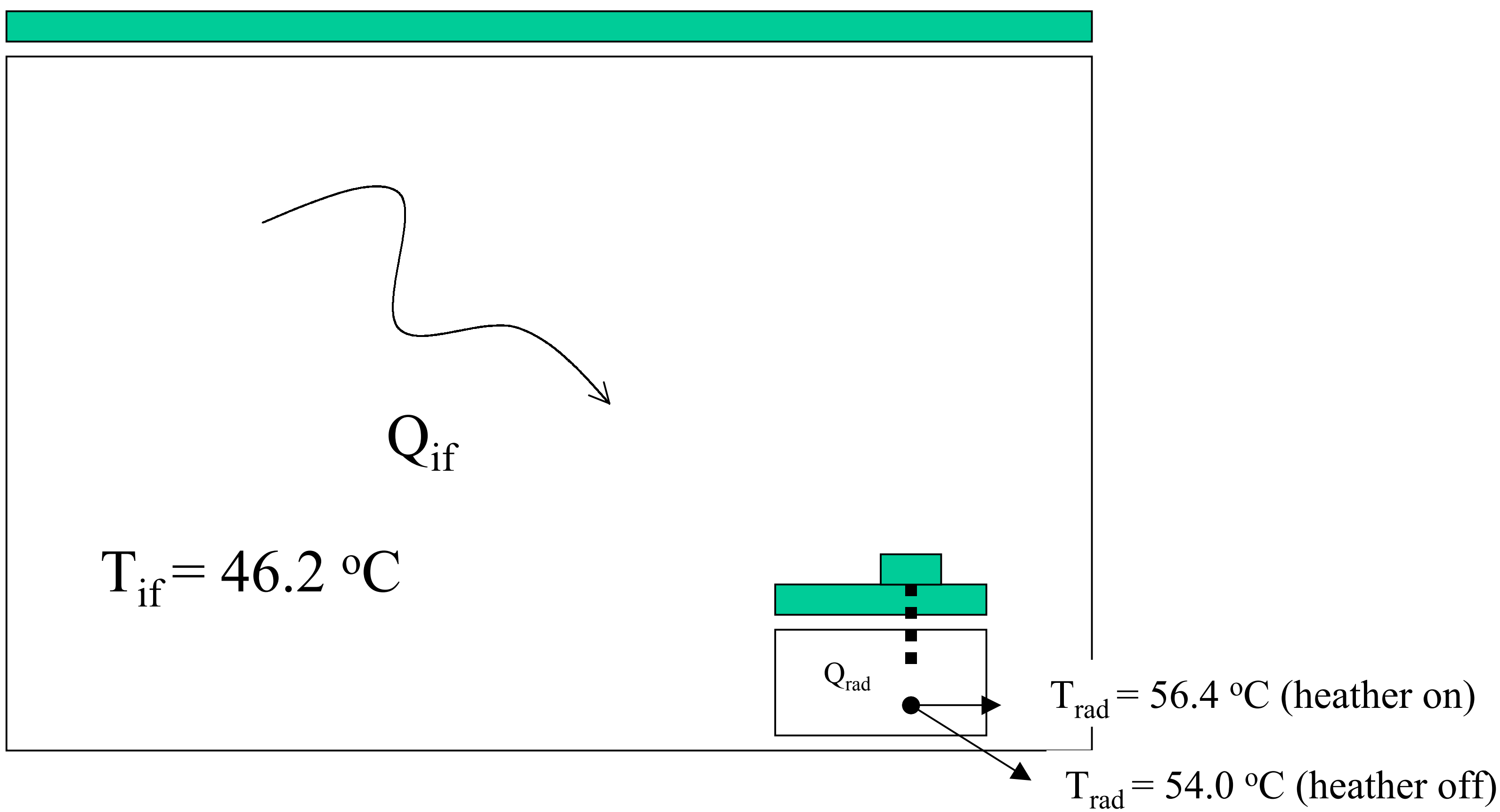


Radiometer Thermal Environment Test

Peter Harbath and R. Acosta

Action Items

Test case 1 – IF Box and Radiometer Box are closed, radiometer heater was on/off.



Action Items

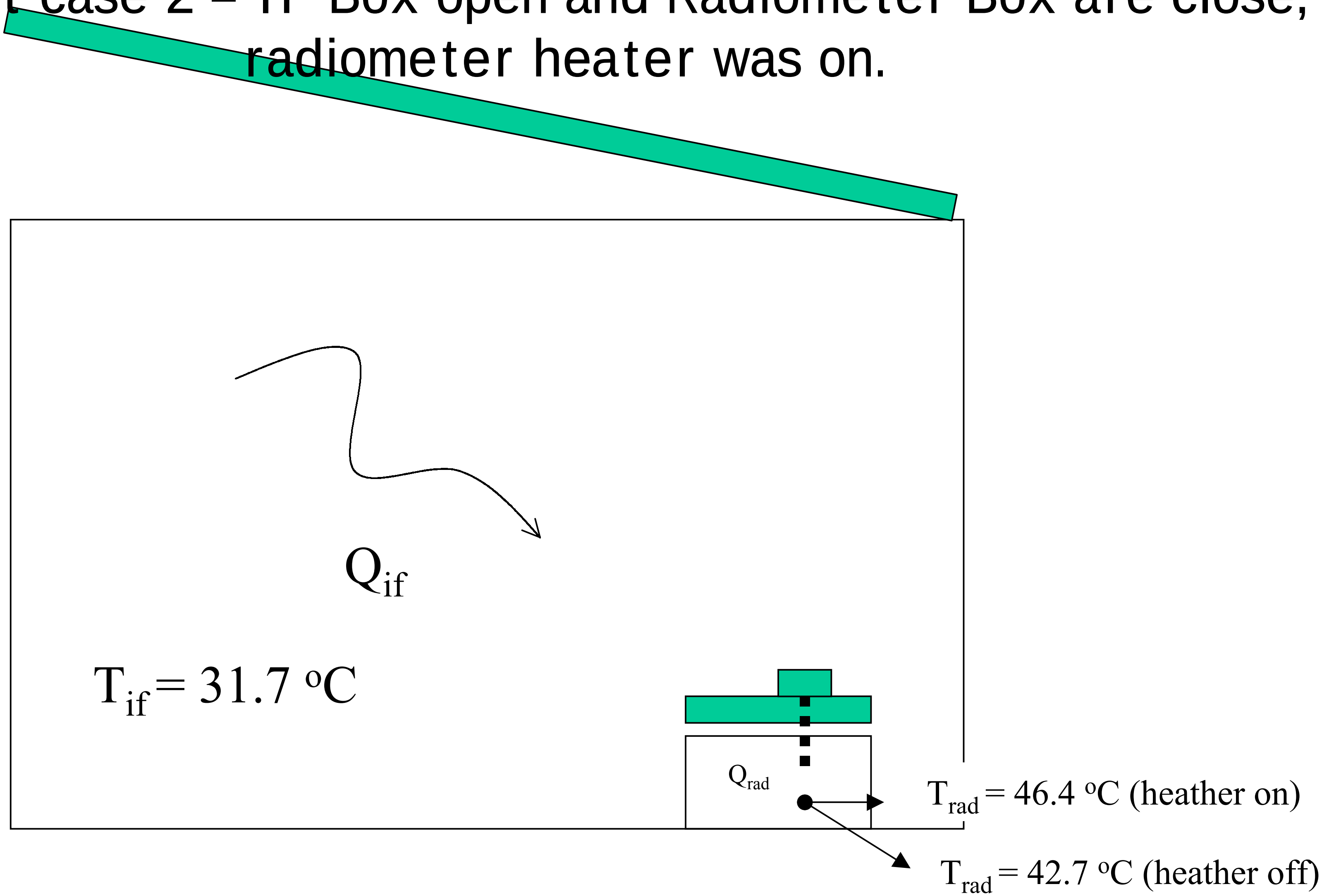
Test case 1 – Conclusions

1- Normal operating conditions on the radiometer and IF boxes calls for a differential temperature of –10.2 degrees C

2- The heather inside the radiometer heats up the radiometer box under normal operating conditions by 2.4 degrees C

Action Items

Test case 2 – IF Box open and Radiometer Box are close, radiometer heater was on.



Action Items

Test case 2 – Conclusions

1- With IF box open the operating conditions on the radiometer and IF boxes calls for a differential temperature of –14.7 degrees C

2- The heather inside the radiometer heats up the radiometer box under this operating conditions by 3.7 degrees C